

UTILITY PATENT
APPLICATION TRANSMITTAL LETTER

JC806 U.S. PTO
 09/692052

 10/20/00

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	

Also enclosed are:

- ☒ 4 sheet(s) of ☒ formal ☐ informal drawing(s);
- ☒ a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 is ☐ hereby made to __
filed in __ on __;
- ☒ in the declaration;
- ☐ a certified copy of the priority document;
- ☐ a General Authorization for Petitions for Extensions of Time and Payment of Fees;
- ☒ an Assignment document;
- ☐ an Information Disclosure Statement; and
- ☐ Other: _____

- [X] An [X] executed [] unexecuted declaration of the inventor(s)
[X] also is enclosed [] will follow.
- [] Please amend the specification by inserting before the first line the sentence --This application claims priority under 35 U.S.C. §§ 119 and/or 365 to _ filed in _ on _; the entire content of which is hereby incorporated by reference.--
- [] A bibliographic data entry sheet is enclosed.
- [] Small entity status is hereby claimed.

[illegible]

CLAIMS					
	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEE
Basic Application Fee					\$710.00 (101)
Total Claims	18	MINUS 20 =	0	× \$18.00 (103) =	0
Independent Claims	3	MINUS 3 =	0	× \$80.00 (102) =	0
If multiple dependent claims are presented, add \$270.00 (104)					
Total Application Fee					710.00
If small entity status is claimed, subtract 50% of Total Application Fee					
Add Assignment Recording Fee \$ if Assignment document is enclosed					40.00
TOTAL APPLICATION FEE DUE					750.00

- ☐ This application is being filed without a filing fee. Issuance of a Notice to File Missing Parts of Application is respectfully requested.
- ☒ A check in the amount of \$ 750.00 is enclosed for the fee due.
- ☐ Charge \$ _____ to Deposit Account No. 02-4800 for the fee due.
- ☒ The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800. This paper is submitted in duplicate.

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Respectfully submitted,

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Date: October 20, 2000

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Image Processor Capable of Reducing Gradation at High Speed

This application is based on application No. 11-299437 filed in Japan, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an image processor, and more particularly, it relates to an image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data (N-arization) on the basis of error diffusion.

Description of the Related Art

An image processor utilizing error diffusion is known in general. General error diffusion is performed on the basis of the following equation.

Assuming that I_{xy} ($0 \leq I_{xy} \leq 1$) represents input image data of a pixel (target pixel) having coordinates (x, y) and B_{xy} (0 or 1) represents output two-valued image data (N-valued image data), two-valued error data E_{xy} is expressed as follows:

$$E_{xy} = I_{xy} - B_{xy} \quad \dots (1)$$

According to the error diffusion, the image data I_{xy} of the target pixel is corrected with an average weighted error $EAVE_{xy}$ of two-valued errors of peripheral pixels thereof, in order to reduce the two-valued error data E_{xy} on the average. The average weighted error $EAVE_{xy}$ is obtained as follows:

$$EAVE_{xy} = \sum K_{ij} \times E_{ij} \quad \dots (2)$$

In general, the weighting factor K_{ij} is increased as approaching the target pixel. As shown in Fig. 3, a filter computes the average weighted error $EAVE_{xy}$ generally with a matrix size i of five pixels along the main scanning direction of the filter and a matrix size j of two to three pixels along the subscanning direction. The weighting factor K_{ij} is increased as approaching the target pixel (denoted by "*" in Fig. 3).

Corrected image data I'_{xy} of the target pixel is expressed as follows:

$$I'_{xy} = I_{xy} + EAVE_{xy} \quad \dots (3)$$

The obtained corrected image data I'_{xy} is binarized with a prescribed threshold Th .

$$\begin{aligned} B_{xy} &= 1 \text{ (when } I'_{xy} \geq Th) \\ B_{xy} &= 0 \text{ (when } I'_{xy} < Th) \end{aligned} \quad \dots (4)$$

5 The two-valued error data E_{xy} is computed from the corrected image data I'_{xy} and a reference value B'_{xy} obtained on the basis of the result of binarization (two-valued image data).

$$E_{xy} = I'_{xy} - B'_{xy} \quad \dots (5)$$

In general, the reference value B'_{xy} is:

$$\begin{aligned} B'_{xy} &= HB \text{ (when } B_{xy} = 1) \\ B'_{xy} &= LB \text{ (when } B_{xy} = 0) \end{aligned} \quad \dots (6)$$

10 The reference values HB and LB are given by the upper limit (= 1) and the lower limit (= 0) of the dynamic range of the pixel respectively.

Fig. 4 is a block diagram showing the structure of a conventional image processor employing error diffusion.

15 Referring to Fig. 4, the image processor is formed by an error storage memory 1, an error computing part (product-sum operation part) 2 computing errors on the basis of an error weighting filter, an adder 3, a comparator 4, a subtracter 5 and a selector 6.

20 The error storage memory 1 stores two-valued errors necessary for computing the average weighted error $EAVE_{xy}$. The error storage memory 1 outputs the two-valued errors to the error computing part 2. The error computing part 2 performs a product-sum operation of the weighting factor K_{ij} and the errors for computing the average weighted error $EAVE_{xy}$ and outputting the same to the adder 3 (the processing of the above equation (2)).

25 The adder 3 adds the image data I_{xy} of the target pixel with the average weighted error $EAVE_{xy}$ of the peripheral pixels and computes the corrected image data I'_{xy} . Then, the adder 3 outputs the corrected image data I'_{xy} to the comparator 4 for binarization and the subtracter 5 for error computing (the processing of the above equation (3)).

30 The comparator 4 compares the corrected image data I'_{xy} with the prescribed threshold Th (e.g. "127") to obtain the two-valued output B_{xy} as a result and outputs the result of the comparison to the selector 6 for selecting the reference value (the processing of the above equation (4)).

The subtracter 5 subtracts the corrected image data I'_{xy} from the reference value B'_{xy} and outputs the obtained two-valued error data E_{xy} to the error storage memory 1 (the processing of the above equation (5)).

5 The selector 6 selects the reference value (HB or LB) for computing the two-valued error data E_{xy} from the two-valued image data B_{xy} , and outputs the selected reference value B'_{xy} to the subtracter 5.

Referring to Fig. 4, the error computing part 2 computing the average weighted error $EAVE_{xy}$ of the peripheral pixels, the adder 3 adding the average weighted error $EAVE_{xy}$ to the input image data I_{xy} and
10 computing the corrected image data I'_{xy} , the comparator 4 comparing the corrected image data I'_{xy} with the threshold Th and computing the two-valued image data B_{xy} , the selector 6 for selecting the reference value B'_{xy} from the two-valued image data B_{xy} and the subtracter 5 computing the two-valued error data E_{xy} from the corrected image data I'_{xy} and the
15 reference value B'_{xy} form a feedback loop of errors.

In order to binarize the image data I_{xy} of the target pixel, the average weighted error $EAVE_{xy}$ of the peripheral pixels must be operated inclusive of a two-valued error $E_{x-1,y}$ of a precedently binarized pixel. In other words, the processing of the above equations (2) to (6) must be entirely performed
20 in a cycle processing a single pixel. If the processing in the feedback loop is performed at a slow speed, therefore, the processing speed of the overall image processor is reduced.

SUMMARY OF THE INVENTION

25 An object of the present invention is to provide an image processor having a high processing speed.

In order to attain the aforementioned object, an image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion according to an aspect of the present invention comprises a correction part correcting the M-valued image data of
30 the target pixel with an N-valued error resulting from N-arization of peripheral pixels for the target pixel and generating corrected image data, an N-arization part comparing the corrected image data with a threshold and converting the corrected image data to N-valued image data of the

target pixel and an output part outputting an N-valued error having a smaller bit number than the corrected image data by multivalued dithering on the basis of the corrected image data and the N-valued image data.

According to another aspect of the present invention, an image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion comprises a correction part correcting the M-valued image data of the target pixel with an N-valued error resulting from N-arization of peripheral pixels for the target pixel and generating corrected image data, an N-arization part comparing the corrected image data with a threshold and converting the corrected image data to N-valued image data of the target pixel and an output part outputting an N-valued error having a smaller bit number than the corrected image data on the basis of the corrected image data and the N-valued image data.

According to still another aspect of the present invention, an image processing method of converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion comprises steps of correcting the M-valued image data of the target pixel with an N-valued error resulting from N-arization of peripheral pixels for the target pixel and generating corrected image data, comparing the corrected image data with a threshold and converting the corrected image data to N-valued image data of the target pixel and outputting an N-valued error having a smaller bit number than the corrected image data on the basis of the corrected image data and the N-valued image data.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the structure of an image processor according to a first embodiment of the present invention;

Fig. 2 is a block diagram showing the structure of an image processor according to a second embodiment of the present invention;

Fig. 3 illustrates the structure of an error weighting filter; and
Fig. 4 is a block diagram showing the structure of a conventional
image processor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a block diagram showing the structure of an image processor
according to a first embodiment of the present invention. The difference
between this image processor and the image processor shown in Fig. 4 is
now described.

According to this embodiment, a multivalued dithering part 7 is
provided between an adder 3 and a subtracter 5. The multivalued
dithering part 7 bit-reduces corrected image data I'_{xy} by multivalued
dithering, and outputs bit-reduced corrected image data I''_{xy} to the
subtracter 5.

The multivalued dithering part 7 applies dithering to lower L bits of
the corrected image data I'_{xy} consisting of K bits and converts the data of
the lower L bits to 1-bit data. Thus, the multivalued dithering part 7
converts the corrected image data I'_{xy} consisting of K bits to the bit-reduced
corrected image data I''_{xy} .

The dithering is a pseudo-gradation method (area gradation method)
expressing gradation by a set of dots similarly to the error diffusion, and
hence the quantity of information per dot is reduced due to the bit
reduction while the quantity of information of the original image is
preserved by the set of the dots.

A selector 6 outputs one of reference values HB and LB in response
to a result B_{xy} of binarization. The reference values HB and LB have the
same bit number as the bit-reduced corrected image data I''_{xy} .

The subtracter 5 subtracts a reference value B'_{xy} from the bit-reduced
corrected image data I''_{xy} and outputs the result as two-valued error data
 E_{xy} . The bit number of the two-valued error data E_{xy} , requiring a bit
indicating \pm , is larger than that of the bit-reduced corrected image data
 I''_{xy} by 1. An error storage memory 1 stores the value of the two-valued
error data E_{xy} .

An error computing part 2 employs an error weighting filter and

outputs an average weighted error $EAVE_{xy}$ with reference to the contents of the error storage memory 1. The error computing part 2 adjusts weighting factors of the error weighting filter thereby matching the bit number of the average weighted error $EAVE_{xy}$ with that of pixel data I_{xy} of a target pixel. The average weighted error $EAVE_{xy}$ is provided with the bit indicating $+/-$, and hence the bit number of the average weighted error $EAVE_{xy}$ is larger than that of the pixel data I_{xy} of the target pixel by 1.

More specifically, the pixel data I_{xy} of the target pixel has eight bits, the corrected image data I'_{xy} has eight bits, the two-valued image data B_{xy} has one bit, the bit-reduced corrected image data I''_{xy} has four bits, the two-valued error data E_{xy} has 1 (indicating $+/-$) + 4 bits, and the average weighted error $EAVE_{xy}$ has 1 (indicating $+/-$) + 8 bits.

According to this embodiment, as hereinabove described, the bit number of computing between the multivalued dithering part 7 and the error computing part 2 can be reduced as compared with the prior art. Thus, high-speed computing can be performed for providing an image processor having a high processing speed.

The capacity of the error storage memory 1 for storing error data can be remarkably reduced by reducing the bit number of the error data.

The sum of the weighting factors of the error weighting filter shown in Fig. 1 is $16 = 2^4$. When the multivalued dithering part 7 reduces four bits, therefore, no division (by "16" in Fig. 4, for example) is required for a product-sum operation of peripheral pixels, to result in no operation error.

Referring to Fig. 1, for example, the error computing part 2 may simply multiply the output from the error storage memory 1 by any of the numerical values "1" to "3" and add the sum, whereby a high-speed operation can be performed.

When a relation $m = 2^n$ holds between the number n of bit reduction by the multivalued dithering and the sum m of the weighting factors, no division is required.

Fig. 2 is a block diagram showing the structure of an image processor according to a second embodiment of the present invention.

While the image processor according to the first embodiment reduces

the bit number of the corrected image data I'_{xy} by multivalued dithering and thereafter computes an N-valued error, the image processor according to the second embodiment reduces the bit number of difference data E_{xy} between corrected image data I'_{xy} and a reference value based on N-valued image data by a multivalued dithering part 7. The bit number of error data can be reduced also by reducing the bit number of the two-valued error E_{xy} , whereby a load on a product-sum operation can be reduced and the speed of a feedback loop for errors can be increased.

While each of the above embodiments has been described with reference to the processing of converting multivalued image data to two-valued image data, the present invention is not restricted to this but is also applicable to image processing converting M-valued image data to N ($M > N$)-valued image data on the basis of error diffusion. In order to reduce the bit number, simple binarization or error diffusion may be employed in place of the multivalued dithering.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

WHAT IS CLAIMED IS:

1. An image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion, comprising:

correction means correcting said M-valued image data of said target pixel with an N-valued error resulting from N-arization of peripheral pixels for said target pixel and generating corrected image data;

N-arization means comparing said corrected image data with a threshold and converting said corrected image data to N-valued image data of said target pixel; and

output means outputting an N-valued error having a smaller bit number than said corrected image data by multivalued dithering on the basis of said corrected image data and said N-valued image data.

2. The image processor according to claim 1, further comprising:

storage means storing said N-valued error output from said output means.

3. The image processor according to claim 2, wherein

said correction means computes an average weighted error on the basis of said N-valued error of said peripheral pixels for said target pixel stored in said storage means and weighting factors, and performs correction on the basis of said average weighted error.

4. The image processor according to claim 3, wherein

a relation $m = 2^n$ holds between the number n of bit reduction by said multivalued dithering and the sum m of said weighting factors.

5. The image processor according to claim 1, wherein

said output means includes means performing multivalued dithering on said corrected image data.

6. The image processor according to claim 5, wherein

said output means generates said N-valued error on the basis of said corrected image data subjected to said multivalued dithering and said n-valued image data.

7. The image processor according to claim 1, wherein
said output means includes means performing multivalued dithering on difference data between said corrected image data and data based on said N-valued image data.

8. An image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion, comprising:
correction means correcting said M-valued image data of said target pixel with an N-valued error resulting from N-arization of peripheral pixels for said target pixel and generating corrected image data;

N-arization means comparing said corrected image data with a threshold and converting said corrected image data to N-valued image data of said target pixel; and

output means outputting an N-valued error having a smaller bit number than said corrected image data on the basis of said corrected image data and said N-valued image data.

9. The image processor according to claim 8, further comprising:
storage means storing said N-valued error output from said output means.

10. The image processor according to claim 9, wherein
said correction means computes an average weighted error on the basis of said N-valued error of said peripheral pixels for said target pixel stored in said storage means and weighting factors, and performs correction on the basis of said average weighted error.

11. The image processor according to claim 8, wherein
said output means includes means performing multivalued dithering

on said corrected image data.

12. The image processor according to claim 11, wherein
said output means generates said N-valued error on the basis of said
corrected image data subjected to said multivalued dithering and said N-
valued image data.

13. The image processor according to claim 8, wherein
said output means includes means performing multivalued dithering
on difference data between said corrected image data and data based on
said N-valued image data.

14. An image processing method of converting M-valued image data
of a target pixel to N ($M > N$)-valued image data by error diffusion,
comprising steps of:

correcting said M-valued image data of said target pixel with an N-
valued error resulting from N-arization of peripheral pixels for said target
pixel and generating corrected image data;

comparing said corrected image data with a threshold and converting
said corrected image data to N-valued image data of said target pixel; and

outputting an N-valued error having a smaller bit number than said
corrected image data on the basis of said corrected image data and said N-
valued image data.

15. The image processing method according to claim 14, further
including:

a step of computing an average weighted error on the basis of said N-
valued error of said peripheral pixels for said target pixel and weighting
factors,

for generating said corrected image data on the basis of said average
weighted error.

16. The image processing method according to claim 14, further

including:

a step of performing multivalued dithering on said corrected image data.

17. The image processing method according to claim 16, wherein said N-valued error is generated on the basis of said corrected image data subjected to said multivalued dithering and said N-valued image data.

18. The image processing method according to claim 14, further including:

a step of performing multivalued dithering on difference data between said corrected image data and data based on said N-valued image data.

5

5

FIG. 1

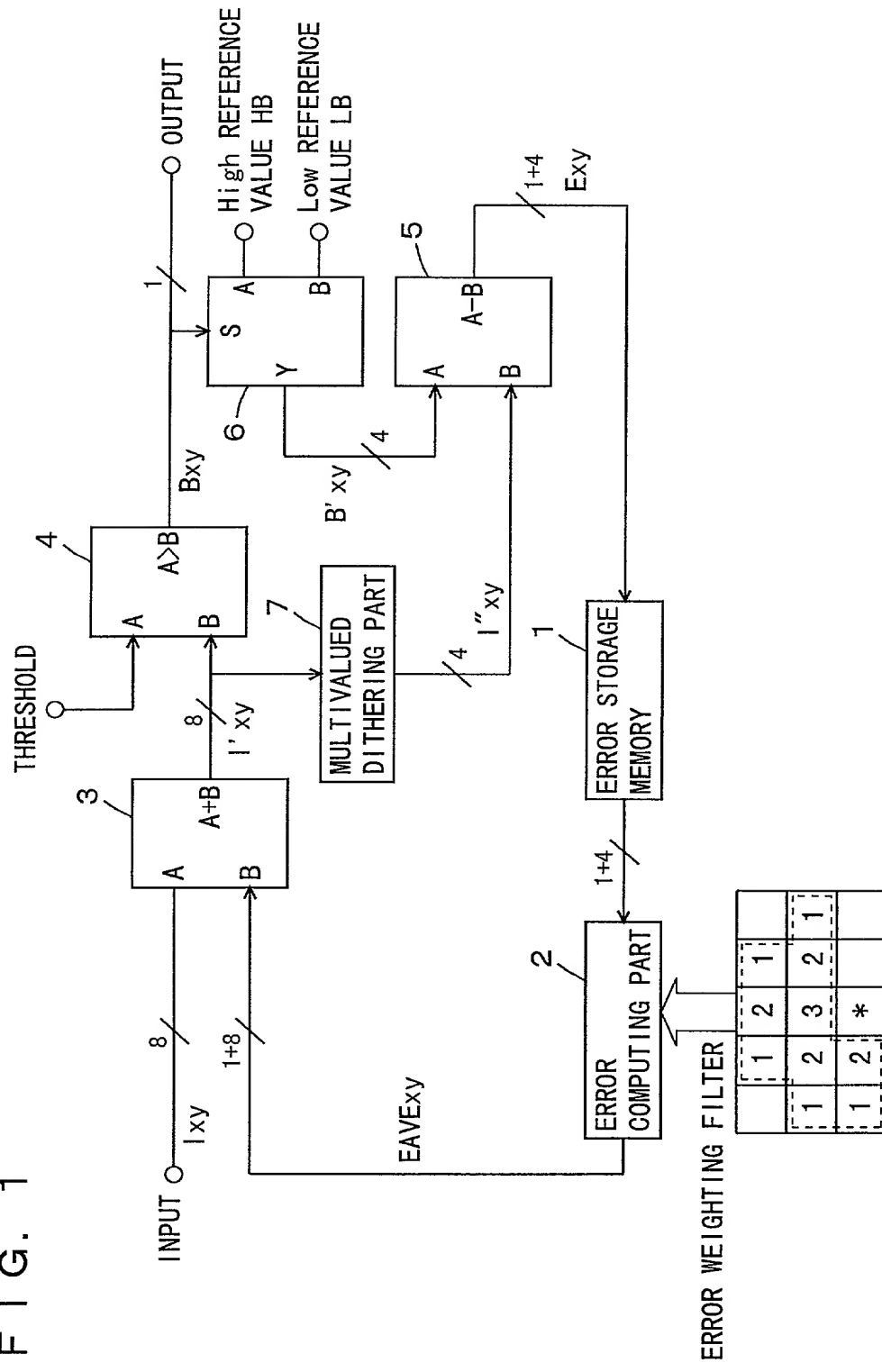
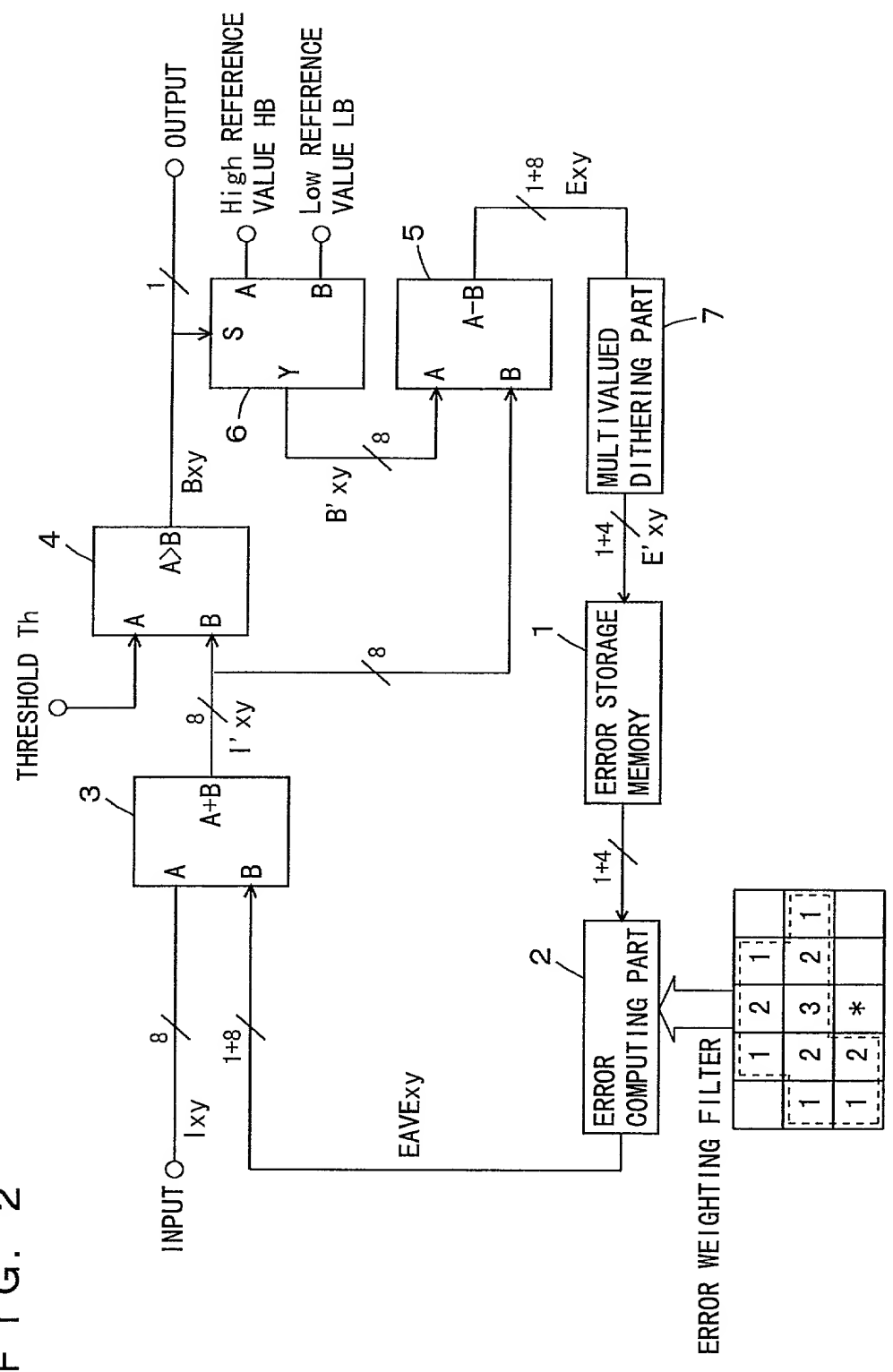


FIG. 2



F I G. 3

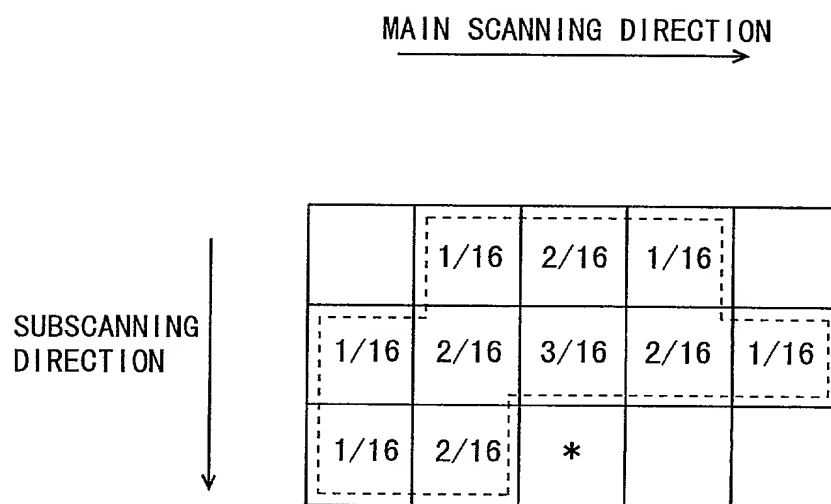
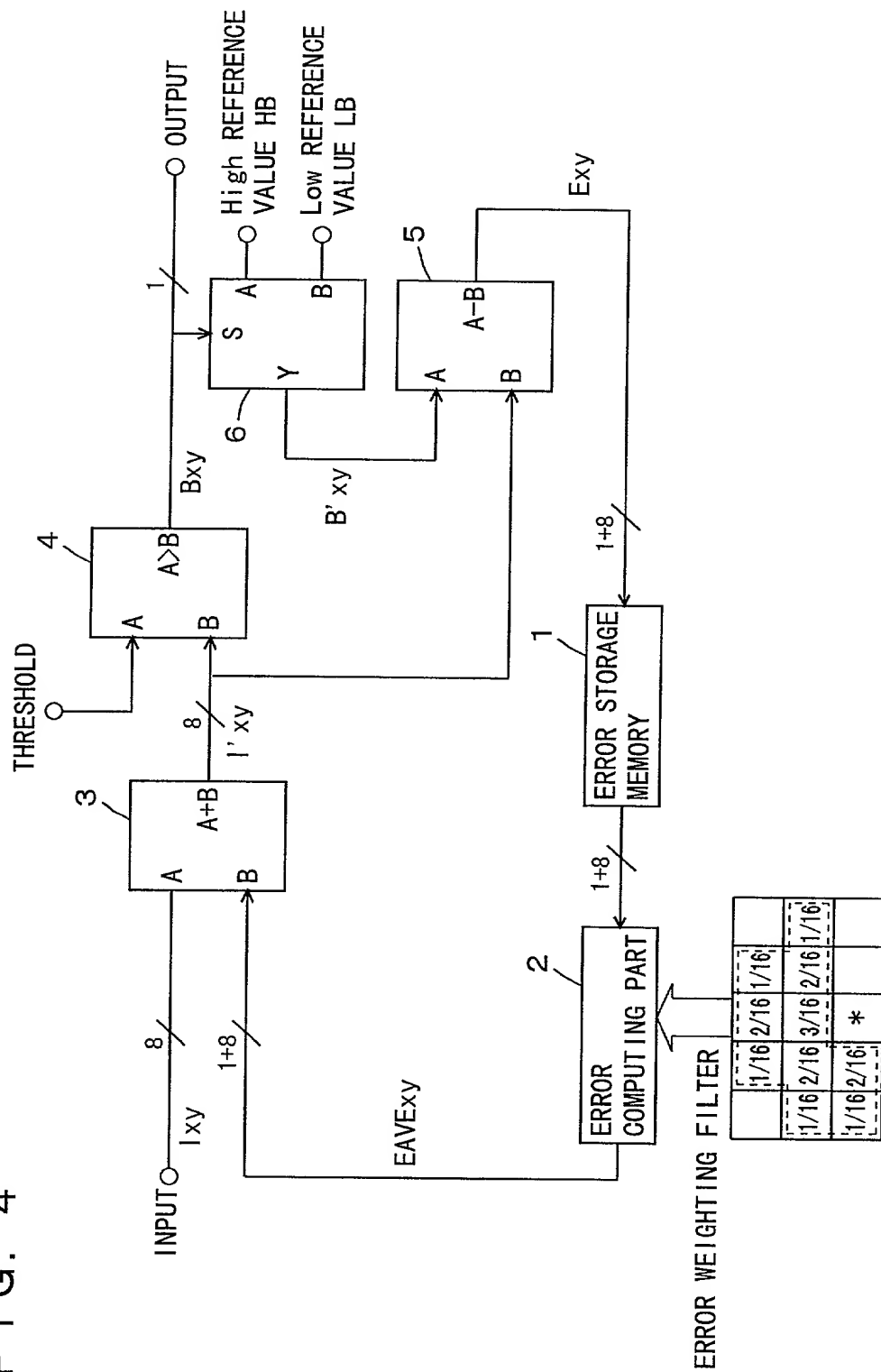


FIG. 4



**COMBINED DECLARATION AND POWER OF ATTORNEY
FOR UTILITY PATENT APPLICATION**

Attorney's Docket No. _____

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I BELIEVE I AM THE ORIGINAL, FIRST AND SOLE INVENTOR (if only one name is listed below) OR AN ORIGINAL, FIRST AND JOINT INVENTOR (if more than one name is listed below) OF THE SUBJECT MATTER WHICH IS CLAIMED AND FOR WHICH A PATENT IS SOUGHT ON THE INVENTION ENTITLED:

IMAGE PROCESSOR CAPABLE OF REDUCING GRADATION AT HIGH SPEED

the specification of which

(check one)

☒ is attached hereto;

☐ was filed on _____ as

Application No. _____

and was amended on _____;
(if applicable)

I HAVE REVIEWED AND UNDERSTAND THE CONTENTS OF THE ABOVE-IDENTIFIED SPECIFICATION, INCLUDING THE CLAIMS, AS AMENDED BY ANY AMENDMENT REFERRED TO ABOVE;

I ACKNOWLEDGE THE DUTY TO DISCLOSE TO THE OFFICE ALL INFORMATION KNOWN TO ME TO BE MATERIAL TO PATENTABILITY AS DEFINED IN TITLE 37, CODE OF FEDERAL REGULATIONS, Sec. 1.56 (as amended effective March 16, 1992);

I do not know and do not believe the said invention was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States of America more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States of America on any application filed by me or my legal representatives or assigns more than twelve months prior to said application;

I hereby claim foreign priority benefits under Title 35, United States Code Sec. 119 and/or Sec. 365 of any foreign application(s) for patent or inventor's certificate as indicated below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application(s) on which priority is claimed:

COMBINED DECLARATION AND POWER OF ATTORNEY

Attorney's Docket No.

COUNTRY/INTERNATIONAL	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED
Japan	11-299437(P)	21/Oct./1999	YESx NO_
			YES_ NO_

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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FULL NAME OF SECOND JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		